Journal of Advances in Medical and Pharmaceutical Sciences

16(3): 1-8, 2018; Article no.JAMPS.40220
ISSN: 2394-1111

Comparative Study of Cardiopulmonary Functions in Trained Male Athletes and Singers– A Pilot Study

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Authors' contributions

This work was carried out in collaboration between all authors. Author OOO designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors PPM and AAM managed the analyses of the study and literature searches. Author MIAS contributed to critically revising the manuscript regarding important intellectual content. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JAMPS/2018/40220
Editor(s):
(1) Jinyong Peng, Professor, College of Pharmacy, Dalian Medical University, Dalian, China.
Reviewers:
(1) P. Schoenhagen, Cleveland Clinic, USA.
(2) Paweł F. Nowak, Opole University of Technology, Poland.
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(4) Maria Justine, Universiti Teknologi MARA, Malaysia.
Complete Peer review History: http://www.sciencedomain.org/review-history/24146

Original Research Article

Received 31st January 2018
Accepted 10th April 2018
Published 14th April 2018

ABSTRACT

Objectives: Studies have shown that both physical exercise and singing have beneficial medical effects on the cardiopulmonary functions of humans in health and disease conditions, but it is not yet known whether physical exercise or singing is more effective in producing these benefits. The aim of this pilot study was to investigate if there is difference between the cardiopulmonary functions in trained male athletes and singers.

Study Design: A total of 20 male human subjects, consisting of 10 trained athletes and 10 trained singers, participated in this study. The ages of the subjects ranged from 20 to 35 years. The trained athletes were individuals who have been engaging in physical exercise under the supervision of a trainer not less than 3 times in a week for 5 years or more. While the trained singers were

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individuals who are members of singing groups and have been singing at least 3 times in a week in the last 5 years or more.

Methods: Each subject was allowed to rest for about 15minutes in order to allow cardiorespiratory parameters return to basal resting levels. Thereafter, pressor, cardiac and pulmonary function parameters of each subject were measured.

Results: Results showed that conduction of impulses within the ventricle (QRS amplitude) and rate of conduction of impulses from the atrium to the ventricle (PR interval) were higher ($P<0.02$ and $P<0.001$ respectively) in trained athletes, while voltage supply during ventricular repolarization (T-wave amplitude) was significantly higher ($P<0.001$) in trained singers. Forced expiratory volume in one second (FEV_1) was higher ($P<0.05$) in trained athletes. Also, there was notable difference ($P<0.001$) in the FEV_1% of trained athletes and trained singers.

Conclusion: The results of this study suggest that there is no significant difference in the cardiovascular functions of trained male athletes and singers, but the effects of physical exercise could be more beneficial than that of singing on the pulmonary function.

Keywords: Blood pressure; electrocardiogram; forced expiratory volume; forced vital capacity; physical exercise; singing.

1. INTRODUCTION

Physical exercise is any bodily activity that enhances or maintains physical fitness and overall health and wellness [1]. Frequent and regular physical exercise boosts the immune system and helps prevent "diseases of affluence" such as cardiovascular disease, type 2 diabetes, and obesity [2,3]. It may also help prevent stress and depression, increase quality of sleep and act as a non-pharmaceutical sleep aid to treat diseases such as insomnia, help promote or maintain positive self-esteem, improve mental health, maintain steady digestion and treat constipation and gas, regulate fertility health, and augment an individual's sex appeal or body image, which has been found to be linked with higher levels of self-esteem [4].

According to the work of Taweesak et al. [5] an 8-week resistance exercise program was shown to improve all pulmonary function parameters in young sedentary subjects. Also, in the works of Spruit et al. [6] and Abrahin et al. [7] a 12-week resistance exercise improved lung functions in patients with chronic obstructive pulmonary disease (COPD) and elderly women respectively. Exercise training has been shown to improve respiratory capacity, airway resistance, exercise tolerance, and work of breathing [8].

In the work of Skinner et al. [9] regular aerobic training induces significant adaptations both at resting and during maximum exercise in a variety of dimensional and functional capacities related to the cardiovascular and respiratory regulation system, enhancing the delivery of oxygen into active muscles, these changes include decreases in heart rate, enhanced stroke volume and cardiac output [10]. Also, Joyner and Tschakovsky, [11] explained the reduction of heart rate, systolic and diastolic blood pressure after aerobic training to be due to Nitric oxide that seems to be an important and potent endothelium-derived relaxing factor that facilitates blood vessel dilatation and decreases vascular resistance.

Hepple [12] reported that peripheral vascular adaptation, which includes enhanced perfusion and flow capacity, has been observed after regular aerobic training. Total leg blood flow during strenuous exercise increases in parallel with a rise in maximal aerobic power. In addition, the arteriovenous oxygen difference in muscle increases after aerobic training. These adaptations may arise from structural modifications of the vasculature and alterations in the control of vascular tone. An increase in the capillary density of muscle has also been shown after training. Both capillary density and blood flow increase in proportion to the rise in maximal aerobic power during long-term aerobic training interventions which may have a strong role in decreasing the heart rate and blood pressure.

Singing, the act of producing musical sounds with the voice, is so basic to human beings that its origins are lost in antiquity, and predate the spoken language. It is well known that respiration has a key role in generating the voice, and it is an essential factor for singing as well [13,14]. In its physical aspect, singing has a well-defined technique that depends on the use of the lungs, which act as an air supply, or bellows; on the larynx, which acts as a reed or vibrator; on the chest and head cavities, which have the function of an amplifier, as the tube in a wind instrument; and on the tongue, which together with the palate, teeth, and lips articulate and impose consonants and vowels on the amplified sound. Though these four mechanisms function independently, they are nevertheless coordinated in the establishment of a vocal technique and are made to interact upon one another [15].

The act of singing involves relatively strong and fast inspirations, followed by extended, regulated expirations. Singing requires breathing to be regulated in order to sustain the notes. It also results in a higher vocal intensity [16] and vocal control [17] than does speaking. Moreover, it has been suggested that singing increases respiratory muscle strength [18].

Research has shown that intensive singing practice can lead to long-lasting changes in both the cardiovascular and pulmonary systems. Grape et al. [19] found out that professional singers have better cardio-physiological fitness, compared to amateur singers, thus providing evidence for the potential long-term health benefits of singing.

In the work of Sabol et al. [20] the primary physiological effects observed were: higher phonation volumes and maximum phonation times, as well as a reduction in airflow. These findings were taken to reflect improved coordination of laryngeal function and vocal fold vibration.

Singing, therefore, requires the presence of an accurate control of breathing. In addition, people who sing are practicing a particular type of respiratory exercise that repeatedly demands diaphragm contractions for full inspirations, followed by sustained contractions of expiratory muscles against semi-closed vocal cords during expirations [21,22]. This training involving breathing control and respiratory muscle exertion has the potential of interfering with the pulmonary function of COPD patients.

From our review of literature, it has been established that both physical exercise and singing have beneficial effects on the cardiovascular and pulmonary functions of human being in health and disease conditions. However, fatigue, mood disturbances, under performance and gastrointestinal distress are common among athletes during training and competition [23]. Recent evidence in murine models shows that there is a high correlation between physical and emotional stress during exercise and changes in gastrointestinal microbiota composition. For instance, exercise-induced stress decreased cecal levels of *Turicibacter* spp and increased *Ruminococcus gnavus,* which have well defined roles in intestinal mucus degradation and immune function [23]. Hence, the need to know whether it is physical exercise or singing that is more effective in producing the stated benefits in literature. The findings from this study will help us to know if trained athletes have more beneficial cardiopulmonary functions than trained singers or vice-versa, and also help us to determine if singing could be recommended instead of exercise in providing solutions to the research problems. The aim of this study was to investigate if there is difference between the pressor parameters, cardiac functions and pulmonary functions in trained male athletes and singers.

2. MATERIALS AND METHODS

2.1 Participants

A total of 20 male human subjects, consisting of 10 trained athletes and 10 trained singers, voluntarily participated in this pilot study. The ages of the subjects ranged from 20 to 35 years. The subjects were informed of the organization and details of the study and signed a consent form. A questionnaire containing health information was given to all subjects for proper screening. Thereafter, the completed questionnaire was retrieved from the proposed participants and properly vetted to determine those who meets the criteria.

2.2 Inclusion Criteria

The subjects were grouped as follows:

Group 1. This group consist of 10 male subjects who are trained athletes. Subjects in this group were individuals who have been engaging in regular physical exercise under the supervision of a trainer not less than 3 times in a week for 5years or more. Also, they were individuals who are not trained singers. Athletes in this study are football and basketball players from the state sport commission.

Group 2: This group consist of 10 male subjects who are trained singers. Subjects in this group were individuals who are members of singing groups and have been singing 3 times in a week in the last 5 years or more. They were also individuals who are not trained athletes.

All subjects were apparently healthy individuals and non-smokers.

3. EXPERIMENTAL PROTOCOL

The experiment was carried out in the Human Physiology Laboratory, College of Medical Sciences, Abubakar Tafawa Balewa University, Bauchi. The experiment was carried out at room temperature. Each subject was allowed to rest for about 15minutes in order to acclimatize to the room environment, and also allow cardiovascular and respiratory parameters return to basal resting levels.

3.1 Anthropometric Measurements

Heights (in meters) of the subjects was measured using an inflexible measuring bar, and values recorded to the nearest 0.05 m. Also, body weights (in kilogram) was measured using a digital weighing scale.

Body mass index (BMI) in Kg/m^2, was calculated by dividing the body weight by the square of the height.

3.2 Measurement of Blood Pressure

Blood pressures were obtained by auscultatory technique using a mercury sphygmomanometer following the principle described by Beevers et al. [24].

The Pulse Pressure (PP) was calculated by finding the difference between the systolic blood pressure (SBP) and diastolic blood pressure (DBP).

Mean arterial blood pressure (MABP) = one-third of pulse pressure + diastolic blood pressure [25].

3.3 Measurement of Electrocardiographic Parameters

A 12-lead, 10 electrodes electrocardiographic (ECG) machine was used for this study. The electrodes shall be positioned as recommended by the American Heart Association [26]. A paper speed of $25mms^{-1}$was used throughout the recording. The machine was standardized at each tracing to show a pen deflection of 10 $mmmV^{-1}$. The following cardiac function parameters were recorded from the ECG paper: P-wave amplitude and duration, QRS amplitude and duration, T-wave amplitude and duration, PR, RR and QT intervals.

To determine heart rate, the R-R distance measured from the ECG reading was inputted into the formula:

$$\frac{25\text{mm/sec}\times 60\text{ beats/minute}}{\text{R-R interval (mm)}} \qquad [25]$$

Where: R-R is the distance between two successive R peaks, 25 mm/sec is the calibration of the ECG machine.

The rate pressure product (RPP) was measured using the formula: systolic blood pressure (mmHg) × heart rate (beats/min) [27], to determine the rate of myocardial oxygen consumption.

3.4 Measurement of Pulmonary Function Parameters

The following pulmonary function parameters were recorded from the readings on the vitalograph following the principle of Kreider, [28]:

Forced Expiratory Volume in one second (FEV_1); Forced Vital Capacity (FVC); FEV_1/FVC Ratio.

4. DATA AND STATISTICAL ANALYSIS

All parameters were measured in trained athletes and trained singers, values obtained were summarized and statistically analysed using SPSS version 23. Comparisons were carried out between both group using non-independent t-test. Results were presented as Mean ± SEM (standard error of mean). P-value of less than 0.05 ($P<0.05$) was considered significant.

5. RESULTS

Tables 1 and 2 show results obtained from male trained athletes and singers. Results were presented in Mean ± Standard Error of Mean (SEM).

5.1 Rate Pressure Product

Fig. 1 shows the rate of myocardial oxygen consumption in male trained athletes and singers.

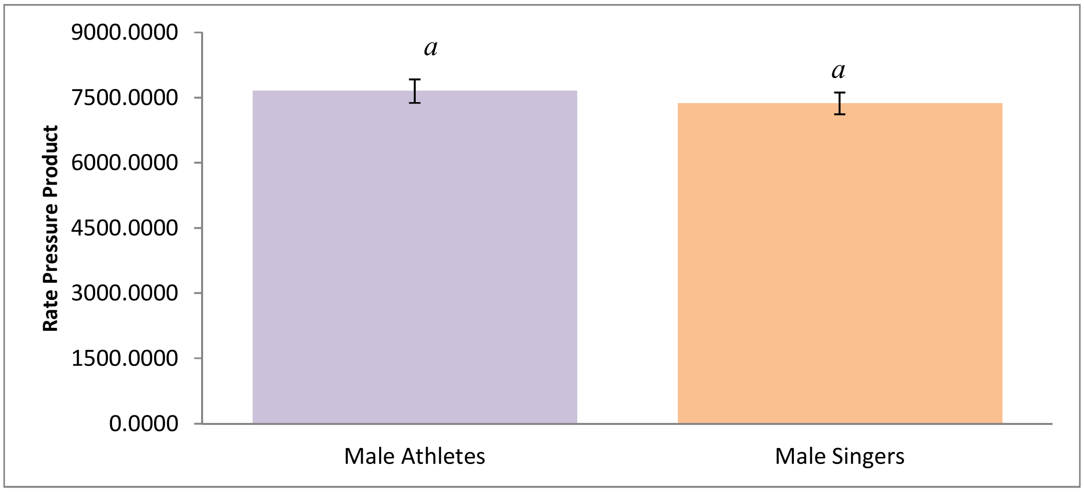

Fig. 1. Comparison of rate pressure product in male athletes and singers

Bar designated with different letter shows significant difference when mean values are compared among the groups

6. DISCUSSION

Table 1 shows higher FEV1 and FEV1% in male athletes compared to male singers. Similar findings had been documented in previous studies by El-Batanouny et al. [29] Seyda et al. [30] Price and Gosling [31]. As far as airways are concerned, activity-induced bronchodilation reduces airway resistance and improves pulmonary ventilation. It is known that normally the volume and pattern of ventilation are initiated by neural output from the respiratory centre in the brainstem. This output is influenced by input from chemoreceptors, proprioceptive receptors in muscles, tendons and joints, and impulses sent by nerves to the intercostal and diaphragmatic muscles [30]. The cause of higher Pulmonary Function Tests values in trained athletes could be due to regular forceful inspiration and expiration for prolonged period during training leading to the strengthening of respiratory muscles [32].

Table 2 shows that trained athletes had higher QRS amplitude and PR-interval, while trained singers had higher T-wave amplitude. Higher QRS amplitude implies increased conduction of impulses within the ventricle. Higher PR-interval implies slow rate of conduction of impulses from the atrium to the ventricle. Higher T-wave amplitude implies increased voltage during ventricular repolarization. Participation in sports activity and regular physical training which is associated with physiological, structural and electrical change in the athletes' heart that enable sustained increases in cardiac output for

Table 1. Anthropometric, pressor function and pulmonary function parameters

	Male athletes	Male singers	P values
Age (yrs)	27.20±1.50[a]	29.60±1.28[a]	0.238
Weight (kg)	67.50± 2.09[a]	64.50±3.19[a]	0.442
Height (m)	1.69±0.03[a]	1.73±0.02[a]	0.344
SBP (mmHg)	123.00±3.00[a]	123.00±3.35[a]	1.000
DBP (mmHg)	77.50±1.34[a]	80.00±0.00[a]	0.079
PP	45.50±3.02[a]	43.00±3.35[a]	0.586
MABP	92.80±4.89[a]	94.50±1.55[a]	0.389
FEV1 (l)	3.10±0.14[a]	2.56±0.21[b]	0.045
FVC (l)	4.82±0.18[a]	4.59±0.27[a]	0.489
FEV1%	64.20±1.52[a]	55.00±1.93[b]	0.001

Values are presented as Mean ± SEM of 10 determinants, Mean value with different superscript letter along the rows are significantly different (P<0.05)

Table 2. Cardiac function parameters

	Male athletes	Male singers	P values
P-wave amplitude (mv)	0.15±0.011[a]	0.13±0.170[a]	0.331
P-wave duration (sec.)	0.11±0.005[a]	0.10±0.004[a]	0.363
QRS amplitude (mv)	1.53±0.117[a]	1.18±0.071[b]	0.020
QRS duration (sec.)	0.09±0.005[a]	0.10±0.006[a]	0.414
T-wave amplitude (mv)	0.23±0.029[a]	0.43±0.036[b]	0.001
T-wave duration (sec.)	0.16±0.015[a]	0.17±0.013[a]	0.619
PR (sec.)	0.19±0.009[a]	0.15±0.005[b]	0.001
RR (sec.)	0.98±0.046[a]	1.00±0.023[a]	0.729
QT (sec.)	0.39±0.010[a]	0.37±0.007[a]	0.346
Heart rate (b/min)	62.70±3.124[a]	60.90±1.501[a]	0.610

Values are presented as Mean ± SEM of 10 determinants, Mean value with different superscript letter along the rows are significantly different (P<0.05)

prolonged periods [33]. ECG changes in athletes are common and usually reflect structural and electrical remodeling of the heart as an adaptation to regular physical training [34,35].

Some of the limitations of this study include lack of material and financial resources to carry out extensive clinical examination to validate the claim of the participants there was no measurement of stress levels of the subjects. These factors might have influenced the results of measured parameters.

7. CONCLUSION

In conclusion, the results of this study suggest that there is no significant difference in the cardiovascular functions of trained male athletes and singers, but the effects of physical exercise could be more beneficial than that of singing on the pulmonary function.

Further studies are recommended to investigate and validate effect of singing on the measured parameters in this study. Also, to validate the claim from this study using larger sample size and considering the limitations of the study.

CONSENT

The subjects were informed of the organization and details of the study and signed a consent form to participate in the study and for the work to be published.

ETHICAL APPROVAL

As per international standard or university standard written ethical permission has been collected and preserved by the authors.

ACKNOWLEDGEMENT

We acknowledge TETFUND Nigeria for their support towards the successful completion of this study.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history/24146